Thermal Dissipation Sap Velocity

- Principle of Measurement
- Specifications
- System overview
- Features & Benefits
- Installation Procedures and tips
- Applications
TDP - How Does it Work

• Probe consists of two needles
  • One incorporating a (-) Reference T-Type Thermocouple
  • One incorporating a (+) T-Type Thermocouple & Heater

• Heated upper needle temperature is compared to lower ambient temperature needle (dT)
  • Maximum dT occurs when the needle is hottest = No Flow
  • Minimum dT occurs when the needle is coolest = High Flow

• dTM - Maximum dT is recorded and averaged pre-dawn = the zero flow set point.
Original Granier Design

Dynamax Improvements

- Smaller Needles
- Internally mounted heater
- Teflon Coated Probes
TDP - Measurement Principle

- Calculate Dimensionless Variable K
  \[ K = \frac{dT_m - dT}{dT} \]
- Calculate Velocity V
  \[ V = 0.000119 \times K^{1.231} \text{ (m/s)} \]
- Calculate Area of Sapwood & multiply to obtain volume flow
  \[ \text{Sapflow} = A \times V \]
Sapwood Area

(A) Outer Bark
(B) Inner Bark
(C) Cambium Layer
(D) Sapwood
(E) Heartwood

- Only the Sapwood conducts water
- Only the sapwood needs to be measured.
- Maritime Pine (Pinus pinaster) – Sapwood thickness = 40-80mm
Sapwood Area Calculations

• Sapwood Area must be calculated to Compute Sapflow

• The method used by Grainer
  • Destructive sample & physically measure
    • Stem cores from a sample of trees
    • Measure DBH
    • Calculate the tree circumference $S_T$
    • Establish Statistical relationship

$$S_A = -0.0039 + 0.59 S_T$$
# TDP-30 Probe Specifications

<table>
<thead>
<tr>
<th><strong>Model</strong></th>
<th><strong>TDP-30</strong></th>
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</thead>
<tbody>
<tr>
<td>Length</td>
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<tr>
<td>Diameter</td>
<td>1.2 mm</td>
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<tr>
<td>T-Type T/C's</td>
<td>1 ea</td>
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<tr>
<td>Probe Spacing</td>
<td>40 mm</td>
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<tr>
<td>Power</td>
<td>0.15 to 0.2 w</td>
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<tr>
<td>Cable Standard</td>
<td>10ft/ 5 cond</td>
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<tr>
<td>Heater Resistance</td>
<td>45 Ohms</td>
</tr>
<tr>
<td>Operating Volts</td>
<td>3.0 V @~8°C</td>
</tr>
<tr>
<td>Signal Out</td>
<td>40 uV/°C</td>
</tr>
</tbody>
</table>

![TDP-30 Probe Diagram](image-url)

- A- Thermocouple #1
- B- Heater
- C- Reference Thermocouple
TDP-50 Probe Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>TDP-50</th>
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<tbody>
<tr>
<td>Length</td>
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<tr>
<td>Diameter</td>
<td>1.65 mm</td>
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<tr>
<td>T-Type T/C's</td>
<td>1 ea</td>
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<tr>
<td>Probe Spacing</td>
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<tr>
<td>Power</td>
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<tr>
<td>Cable Standard</td>
<td>10ft/ 5 cond</td>
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<tr>
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<tr>
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<tr>
<td>Signal Out</td>
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</tbody>
</table>
## TDP-80 Probe Specifications

**Model**
- **Length**: 80 mm
- **Diameter**: 1.65 mm
- **T-Type T/C's**: 2 ea

**Probe Spacing**: 40 mm
**Power**: 0.4 to 0.5 W
**Cable Standard**: 10ft/ 7 cond
**Heater Resistance**: 100 Ohms
**Operating Volts**: 7.5 V @ ~8°C
**Signal Out**: 40 uV/°C

**Diagram**:

- **A**: Thermocouple #1
- **B**: Thermocouple #2
- **C**: Heater
- **D**: Reference Thermocouple
- **E**: Reference Thermocouple
Sap Flow Calculation - Conifer

![Graph showing sap flow calculation for different time periods and tree types.](image-url)
Specifications Summary

- Free flexible cable between needles of the sensor specifically designed to improve installation and removal of probes.

- Sensors constructed using solid or epoxy encapsulation methods causes sensor damage during removal. Non-reusable.

- Modified Hypodermic syringe minimizes probe diameter

- Grainer concluded the smaller diameter of DYNAMAX design is pivotal to improved responsiveness of DYNAMAX TDP probes over his original prototype.
How Many Sensors Not How Long!

- Uniform Growth Conditions
- Non-uniform Growth Conditions
TDP-30 Species Compatibility

(1) Ring-porous Species
   • Large Early wood vessels to small Late wood

(2) Thin xylem

(3) Pinus & Oak Species
   • *Pinus radiata* - Monterey Pine
   • *Pinus caribaea* - Caribbean Pine
   • *Quercus petraea* – Sessile Oak
TDP-50 Species Compatibility

(1) Ring-porous Species
(2) Mature trees with medium Sapwood

- *Pinus strobus* - Eastern White Pine
- *Juglans nigra* - Black Walnut
- *Toona australis* – Red Cedar
- *Pseudotsuga menziesii* – Douglas Fir
TDP-80 Species Compatibility

(1) Diffuse-porous Species
   • No differentiation between early wood & late wood

(2) Plants with > 30% Sapwood
   • *Populus Deltoides* - Cottonwood
   • *Acer rubrum* - Red Maple
   • *Eucalyptus regnans* – Mountain Ash
   • *Phytolacca dioca* - Ombu Tree
   • *Mangifera Indica* – Mango Tree
# TDP Sensors

## Features
- INRA research (Granier) design
- Verified & supported math
- Two needles epoxy sealed
- Teflon coated probes
- International License
- Multiple probe size
- One differential channel
- Low voltage operation

## Benefits
- Continuous Sap Velocity
- Simple data calculation/analysis
- Durable, Reusable Design
- Real-Time Data Acquisition
- Monitor multiple trees
- Monitor large trees
- Universal logger compatibility
- Easy voltage regulation
TDP Probe Installation
Installation Procedure

1. Prepare the Probe Site:
   - Select a height 1-2 meters above the ground
   - Remove old rough bark to cambium layer

2. Drill Holes:
   - Place the Drilling Jig flat on the prepared surface
   - Drill a hole with the smallest drill bit
   - Enlarge the hole with the larger drill bit (if Required)

3. Install Probes:
   - Insert the heater in the top hole & the reference in the bottom
   - Insert needles slowly and gradually
   - Tape cables to the tree for support
Insulation & Sensor Removal

• Insulation:
  • Install a water proof seal around the needles
  • Secure Foam Quarter spheres around probes
  • Install thermal insulation using reflective foam Bubble Wrap

• Probe Removal:
  • Do NOT pull on the base of the needle
  • Never use Claw hammers or other long Levers
  • Always use the supplied nail removing Pry-bar
  • Address the cannula with the pry-bar then, using moderate force withdraw the probes gradually.
Applications

- Forestry Research
- Commercial Forestry
- Transpiration Research
- Phytoremediation
- Carbon Sequestration
Forestry Research

• Stand Transpiration for projection of Biomass production
• Effects of thinning on tree water use
• Species Water Use requirements for new plantations on marginal land
Commercial Forestry

• Effectiveness of regeneration techniques after harvesting.

• Growth rate modeling for harvesting projections
Transpiration Research

- Whole tree water use
- Transpiration correlation to photosynthesis, light, soil & water
- Spatial variations in xylem sap flux density
- Irrigation efficiencies of mature citrus trees
- Drought tolerance of tree species
Phytoremediation

- Hydraulic containment of contaminated groundwater.
  - Groundwater level reduction
  - Tree stores contaminants
- Calculation of water removal rate
  - Net Stand transpiration rate
  - Determine current removal rate
  - Project future removal rate
Carbon Credits Trading

- Carbon Sequestration
  - New research to determine species carbon accumulation or storage rates and capacities.
  - Used for future environmental trading
  - Offset CO₂ emissions